

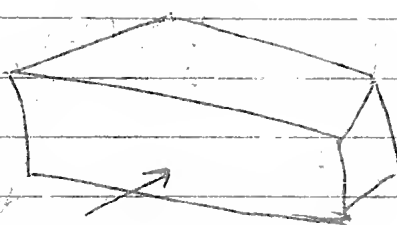
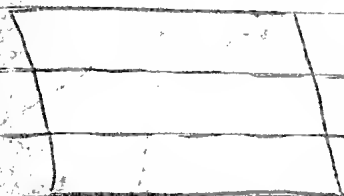
lec (13)

$$P_e = \frac{h\nu}{KT} e^{-h\nu/KT}$$

At thermal Equilibrium

Prob of emission at Quasi equilibrium

E_2

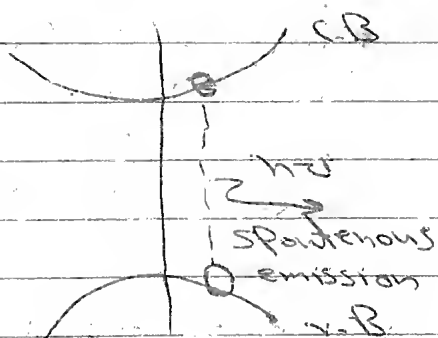


E_1 Dirac Blac + Bumping

$$f_e(E_2) [1 - f_v(E_1)]$$

$$\frac{e^{-(E_2 - E_Fc)/KT}}{1 + e^{-(E_2 - E_Fc)/KT}} \left[1 - \frac{e^{-(E_1 - E_Fv)/KT}}{1 + e^{-(E_1 - E_Fv)/KT}} \right]$$

$$\frac{1}{1 + e^{-(E_2 - E_Fc)/KT}} \frac{e^{-(E_1 - E_Fv)/KT}}{1 + e^{-(E_1 - E_Fv)/KT}}$$



Apply Boltzmann Approx

$$(E_2 - E_Fc) \gg KT$$

$$(E_1 - E_Fv) \gg KT$$

$$\frac{e^{-(E_2 - E_Fc)/KT}}{1 + e^{-(E_2 - E_Fc)/KT}} \frac{e^{-(E_1 - E_Fv)/KT}}{1 + e^{-(E_1 - E_Fv)/KT}}$$

$$\frac{e^{-(E_2 - E_Fc)/KT}}{1 + e^{-(E_2 - E_Fc)/KT}} \frac{e^{-(E_Fc - E_Fv)/KT}}{1 + e^{-(E_Fc - E_Fv)/KT}}$$

(1)

$$P_e = \frac{h\nu}{e} \frac{e^{-(E_Fc - E_Fv)/kT}}{e^{-(E_Fc - E_Fv)/kT}}$$

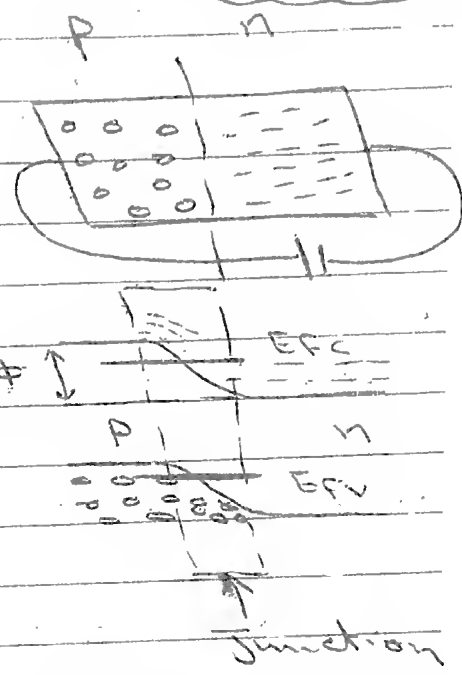
$E_{Fc} > E_{Fv}$

GaAs

لا يملك الفولتية

PN junction

Forward Bias



Rate of spontaneous emission

الانبعاث التلقائي

$$R_{sp} = \frac{1}{\tau_r} \rho(\nu) P_e$$

$\rho(\nu)$ = optical joint Density

τ_r = time of Recombination

No of emitted Photons per unit time per unit volume per unit energy (freq)

$\rho(\nu)$ → No of emitted or absorbed Photon per unit volume per unit energy

Joint → 2 allowed states
valan & cond bands

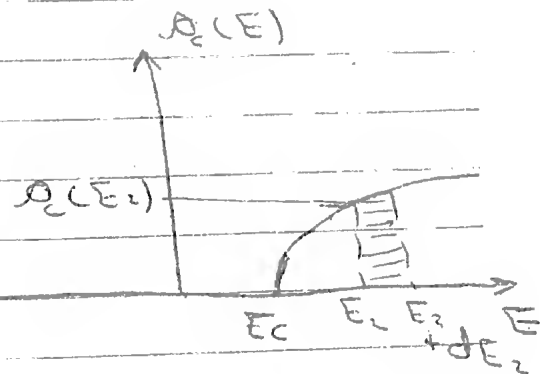
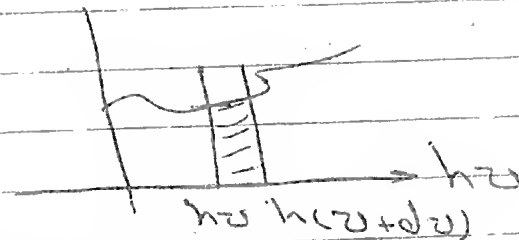
(2)

No. of allowed states $(E_2 \rightarrow E_2 + dE_2)$
 per unit volume

$$= \rho_c(E_2) dE_2$$

$$\rho(\nu) d\nu$$

↑ ↑
 Per unit volume Freq

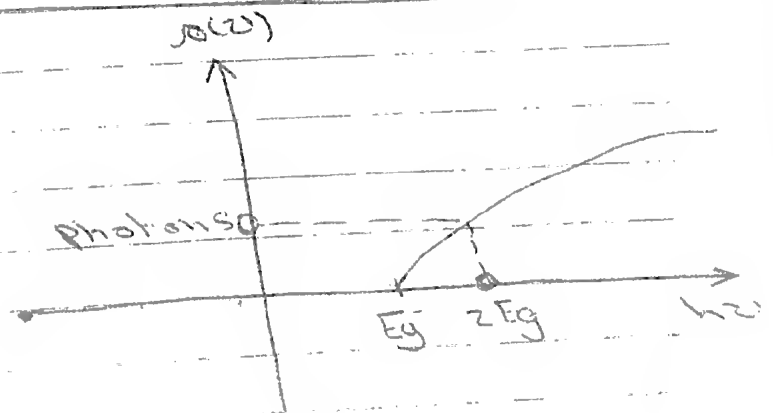


$$\rho_c(E_2) dE_2 = \rho(\nu) d\nu$$

$$\rho(\nu) = \rho_c(E_2) \frac{dE_2}{d\nu}$$

$$\rho(\nu) = \frac{1}{2\pi^2} \left(\frac{2m_e}{h^2} \right)^{3/2} (E_2 - E_c)^{1/2} \cdot \frac{m_e h}{m_e} \left(\frac{m_e}{m_e} \right)^{1/2} (h\nu - E_g)^{1/2}$$

$$\rho(\nu) = \frac{1}{\pi h^2} (2m_e)^{3/2} (h\nu - E_g)^{1/2}$$



$$S_{sp} = \frac{1}{2\pi\hbar^2} (2m_r)^{3/2} (-E_g + \hbar\omega)^{1/2} e^{-\hbar\omega/kT}$$

→ rate of spontaneous emission at thermal equilibrium

$$S_{sp} \propto e^{(E_{fc} - E_{fv})/kT}$$

Quasi eq

$$S_{sp} = \frac{1}{2\pi\hbar^2} (2m_r)^{3/2} e^{-E_g/kT} [\hbar\omega - E_g]^{1/2} e^{-\hbar\omega/kT}$$

$$S_{sp} = D_0 T^{1/2} e^{-Px}$$

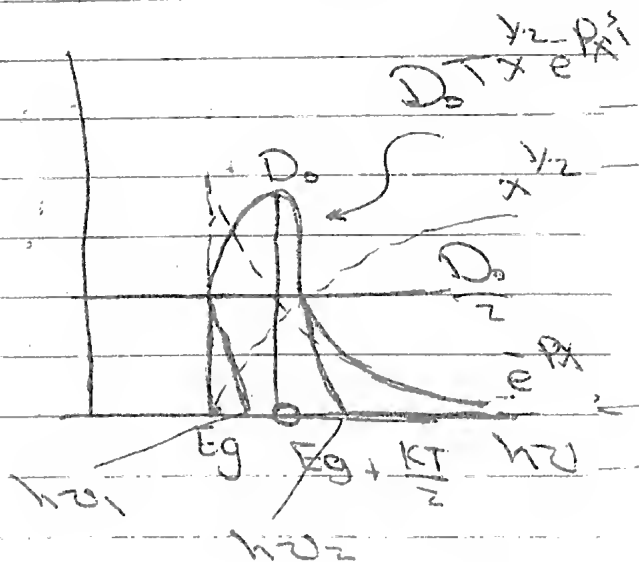
$$P = \frac{1}{kT}$$

$$\hbar\omega = E_g + \frac{kT}{2}$$

half power
beam width

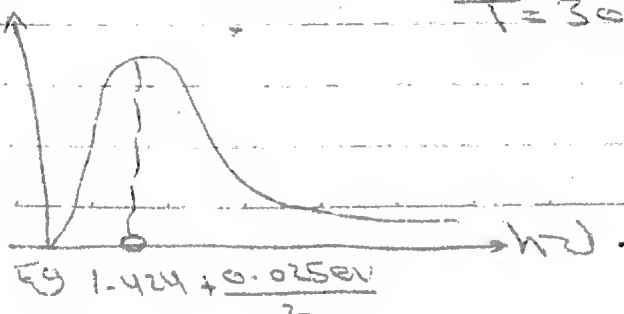
$$\lambda = 1.45 kT \lambda^2$$

$$\omega = 1.45 kTc$$



$$x) \text{ GaAs } E_g = 1.424 \text{ eV}$$

$$T = 300 \text{ K}$$



5

Subject: _____

Date: _____

GAN

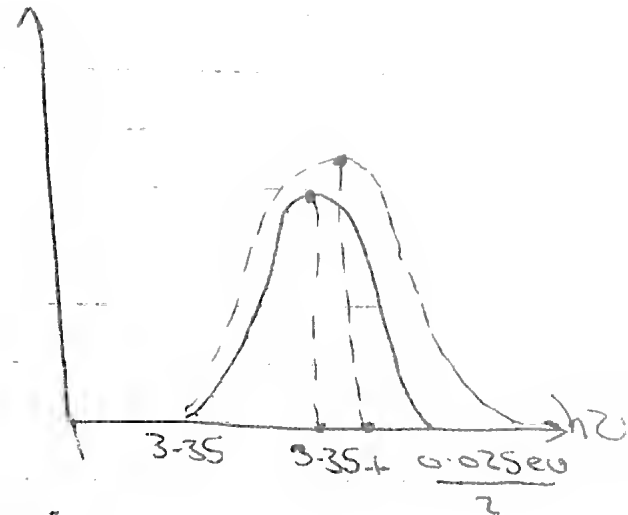
$$E_g = 3.35 \text{ eV}$$

$T \uparrow$

$Q \uparrow$

$Q(T) \uparrow$

$BW \uparrow$



وإذا لم يكن! يعني

① Semicond Direct mat

② Bumping Forward Bias